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**NOT MEASUREMENT SENSITIVE**

**DOE-HDBK-1105-2002**
**February 2002**

**Superseding**
**DOE-HDBK-1105-96**
**December 1996**

# DOE HANDBOOK

# RADIOLOGICAL TRAINING FOR TRITIUM FACILITIES

**U.S. Department of Energy**
**Washington, D.C. 20585**

**AREA TRNG**

(PART 1 OF 4)

# Radiological Training for Tritium Facilities

# Program Management Guide

Coordinated and Conducted
for
Office of Environment, Safety & Health
U.S. Department of Energy

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## Table of Contents

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## Introduction

### Purpose and Scope

This beginning section discusses in general recommendations for the implementation of radiation safety training. Course specific guidance begins on page 11

This Handbook describes a recommended implementation process for conducting the radiation safety training required by Title 10 Code of Federal Regulations *Occupational Radiation Protection*, (10 CFR 835) Subpart J and as outlined in the DOE standard DOE-STD-1098-99, *Radiological Control* (RCS). The Handbook is to assist those individuals, both within the Department of Energy (DOE) and Managing and Operating (M&O) contractors, identified as having responsibility for implementing the training required by 10 CFR 835 and recommended by the RCS.

### Management Guide Content

The management guide is divided into the following sections:

- Introduction
- Instructional Materials Development
- Training Program Standards and Policies
- Course Specific Information

### Training Program Goal

The goal of the training program is to provide a baseline knowledge for those individuals completing the training. Use of the DOE developed material provides personnel with the information necessary to perform their assigned duties at a predetermined level of expertise. Implementing the training program helps ensure consistent and appropriate training of personnel.

### Organizational Relationships and Reporting Structure

The DOE Office of Worker Protection Policy and Programs (EH-52) is responsible for approving and maintaining the DOE developed training materials associated with the training program.

The establishment of a comprehensive and effective contractor site radiological control training program is the responsibility of line management and their subordinates. The training function can be performed by a separate training organization, but the responsibility for quality and effectiveness rests with the line management.

## Instructional Materials Development

### Target Audience

Course instructional materials were developed for specific employees who are responsible for knowing or using the knowledge or skills for each course. With this in mind, the participant should never ask the question, "Why do I need to learn this?" However, this question is often asked when the participant cannot apply the content of the program. It is the responsibility of management to select and send workers to training who need the content of the program. When workers can benefit from the course, they can be motivated to learn the content and apply it on their jobs. Care should be taken to read the course descriptions along with the information about who should attend. Participants and DOE facilities alike will not benefit from workers attending training programs unsuitable for their needs.

### Prerequisites

A background and foundation of knowledge facilitates the trainee in learning new knowledge or skills. It is much easier to learn new material if it can be connected or associated to what was previously learned or experienced. Curriculum developers who have been involved in preparing instructional materials for the core training know this and have established what is referred to as "prerequisites" for each course.

Certain competencies or experiences of participants were also identified as necessary prior to participants attending a course. Without these competencies or experiences, the participants would be at a great disadvantage and could be easily discouraged and possibly fail the course. It is not fair to the other participants, the unprepared participant, and the instructor to have this misunderstanding.

### Training Material

Training materials for the program consist of lesson plans, study guides and handouts. The training content should be presented in its entirety. Overhead transparencies are provided in support of the training content and may be substituted or supplemented with updated or site-specific information.

Supplemental material and training aids may be developed to address site-specific radiological concerns and to suit individual training styles. References are cited in each lesson plan and may be used as a resource in preparing site-specific information and training aids.

Each site is responsible for establishing a method to differentiate the site-specific information from the DOE developed lesson plan material. When additional or site-specific information is added to the text of the core lesson plan material, a method should be used to differentiate site information from DOE developed material.

**Exemptions**

Qualified personnel can be exempted from training if they have satisfactorily completed training programs, (i.e., facility, college or university, military, or vendor programs) comparable in instructional objectives, content, and performance criteria. Documentation of the applicable and exempted portions of training should be maintained.

**Training Program Standards and Policies**

**Qualification of Instructors**

The technical instructor plays a key role in the safe and efficient operation of DOE facilities. Workers must be well qualified and have a thorough understanding of the facility's operation, such as processing, handling, and storage of materials, and maintenance of equipment. Workers must know how to correctly perform their duties and why they are doing them. They must know how their actions influence other worker's responsibilities. Because workers' actions are so critical to their own safety and the safety of others, their trainers must be of the highest caliber. The technical instructor must understand thoroughly all aspects of the subjects being taught and the relationship of the subject content to the total facility. Additionally, the instructor must have the skills and knowledge to employ the instructional methods and techniques that will enhance learning and successful job performance. While the required technical and instructional qualifications are listed separately, it is the combination of these two factors that produces a qualified technical instructor.

The qualifications are based on the best industry practices that employ performance-based techniques to ensure that workers receive the highest quality training possible. This is possible only when technical instructors possess the technical competence and instructional skills to perform assigned instructional duties in a manner that promotes safe and reliable DOE facility operations.

**Technical Qualifications**

Instructors must possess technical competence (theoretical and practical knowledge along with work experience) in the subject areas in which they conduct training. The foundation for determining the instructor's technical qualifications is based on two factors:

- the trainees being instructed, and
- the subject being presented

The following is an example of a target audience, subject to be taught, and instructor technical qualifications.

| TARGET AUDIENCE | SUBJECT BEING TAUGHT | INSTRUCTOR TECHNICAL QUALIFICATIONS |
|---|---|---|
| Tritium Facilities Personnel, Visitors, DOE Employees | Tritium Hazards and Safety Training | Demonstrated knowledge and skills in radiation protection, above the level to be achieved by the trainees, as evidenced by previous training/education and through job performance,<br>AND<br>Completion of all qualification requirements for the senior-level radiation protection technician position at the trainees' facility or a similar facility. |

Methods for verifying the appropriate level of technical competence may include the review of prior training and education, observation, and evaluation of recent related job performance, and oral or written examination. Other factors that may be appropriate for consideration include DOE, NRC, or other government qualification, certification by the American Board of Health Physics and/or registration by the National Registry of Radiation Protection Technologists, vendor or facility certification, and most importantly, job experience. To maintain technical competence, a technical instructor should continue to perform satisfactorily on the job and participate in continuing technical training.

**Instructional Capability and Qualifications**

Qualifications of instructional capability should be based on demonstrated performance of the instructional tasks for the specific course requirements and the instructor's position. Successful completion of instructor training and education programs, as well as an evaluation of on-the-job performance, is necessary for verification of instructional capability. Instructional capability qualification should be granted as the successful completion of an approved professional development program for training instructors. The program should contain theory and practice of instructional skills and techniques, adult learning, planning, conducting, and evaluating classroom, simulator, laboratory, and on-the-job training activities.

Illustrated talks, demonstrations, discussions, role playing, case studies, coaching, and individual projects and presentations should be used as the principal instructional methods for presenting the instructional training program. Each instructional method should incorporate the applicable performance-based principles and practices. Every effort should be made to apply the content to actual on-the-job experience or to simulate the content in the classroom/laboratory. The appropriate methodology required to present the instructional content will indicate a required level of instructional qualification and skill.

Current instructors' training, education, and job performance should be reviewed to determine their training needs for particular courses. Based on this review, management may provide exemptions based on demonstrated proficiency in performing technical instructor's tasks.

Through training or experience, technical instructors should be able to*:

- Review instructional materials and modify them to fully meet the needs of the training group.
- Arrange the training facility (classroom/laboratory or other instructional setting) to meet the requirements for the training sessions.
- Effectively communicate, verbally and non-verbally, lessons to enhance learning.
- Invoke student interaction through questions and student activities.
- Use appropriate instructional materials and visual aids to meet the lesson objectives.
- Administer performance and written tests.
- Ensure that evaluation materials and class rosters are maintained and forwarded to the appropriate administrative personnel.
- Evaluate training program effectiveness.
- Modify training materials based on evaluation of training program.

*Stein, F. *Instructor Competencies: The Standards.* International Board of Standards for Training, Performance and Instruction; 1992.

**Selection of Instructors**

Selection of instructors should be based on the technical and instructional qualifications specified in the Course Specific Information section of this guide. In addition to technical and instructional qualifications, oral and written communication skills, and interpersonal skills, should be included in the process of selecting and approving instructors.

Since selection of instructors is an important task, those who share in the responsibility for ensuring program effectiveness should:

- interview possible instructors to ensure they understand the importance of the roles and responsibilities of technical instructors and are willing to accept and fulfill their responsibilities in a professional manner
- maintain records of previous training, education, and work experience

Procedures for program evaluation will include documentation of providing qualified instructors for generic and site-specific training programs.

**Test Administration**

A test bank of questions for this training, with site specific information, should be developed and the content validated. As the test banks are used, statistical validation of the test bank should be performed in order to fully refine the questions and make the tests as effective as possible. The questions contained in the test bank are linked directly to the objectives for each course. In this way, trainee weaknesses can be readily identified and remedial procedures can be put into place. The test outcomes can also be used to document competence and the acquisition of knowledge.

The test banks should also be used by the instructors to identify possible weaknesses in the instruction. If numerous trainees fail to correctly answer a valid set of questions for an objective, the instruction for that objective needs to be reviewed for deficiencies.

Written examinations should generally be used to demonstrate satisfactory completion of theoretical classroom instruction. The following are some minimal recommendations for the test banks and tests:

- Tests are randomly generated from the test bank.
- Test items represent all objectives in the course.
- All test bank items are content-validated by a subject matter expert.
- Test banks are secured and are not released either before or after the test is administered.
- Trainees receive feedback on their test performance.
- Test banks undergo statistical analysis.
- For the first administrations of tests, a minimum passing score of 80% should be required for a passing score. As statistical analysis of test results is performed, a more accurate percentage for a passing score should be identified.

Test administration is critical in accurately assessing the trainee's acquisition of knowledge being tested. Generally, the following rules should be followed.

- Tests should be announced at the beginning of the training sessions.
- Instructors should continuously monitor trainees during completion of tests.
- All tests and answers should be collected at the conclusion of each test.
- No notes can be made by trainees concerning the test items.
- No talking (aside from questions) should be allowed.
- Answers to questions during a test should be provided but answers to test items should not be provided or alluded to.
- Where possible, multiple versions of each test should be produced from the test bank for each test administration.
- After test completion, trainees may turn in their materials and leave the room while other trainees complete their tests.
- Trainee scores on the tests should be held as confidential.

**Program Records and Administration**

Training records and documentation shall meet the requirements of 10 CFR 835.704.

**Training Program Development/Change Requests**

All requests for program changes and revisions should be sent to the DOE Technical Standards Program using the form "Document Improvement Proposal" provided at the conclusion of the material, as provided on the DOE Technical Standards website.

**Audits (internal and external)**

Internal verification of training effectiveness should be accomplished through senior instructor or supervisor observation of practical applications and discussions of course material. All results should be documented and maintained by the organization responsible for Radiological Control training.

The training program materials and processes is evaluated on a periodic basis by DOE-HQ. The evaluation includes a comparison of program elements with applicable industry standards and requirements.

**Evaluating Training Program Effectiveness**

Verification of the effectiveness of Radiological Control Training for Supervisors should be accomplished by surveying a limited subset of former students in the workplace. This evaluation should include observation of practical applications and discussion of the course material. DOE/EH has issued guidelines for evaluating the effectiveness of radiological training through the DOE Operations Offices and DOE Field Offices. These guidelines are available as an attachment to the Program Management Guide of DOE-HDBK-1122-99, Radiological Control Technician Training.

For additional guidance, refer to DOE STD 1070-94, A Guide for Evaluation of Nuclear Facility Training Programs. The guidelines contained in these documents are relevant for the establishment and implementation of post-training evaluation programs.

## Course-Specific Information

**Purpose**

This section of the program management guide is to assist those individuals assigned responsibility for implementing the *Radiological Training for Tritium Facilities*. Standardized implementation of this training helps ensure consistent and appropriate training for all personnel.

**Course Goal**

Upon completion of this training, the student will have a basic understanding of the characteristics of tritium and understand the precautions and safeguards needed for working in a tritium facility.

**Target Audience**

Individuals who have assigned duties in tritium facilities.

**Course Description**

This course illustrates and reinforces the skills and knowledge needed to provide personnel with an understanding of the characteristics of tritium and the precautions needed for working with or around it in a DOE facility. This course is designed to meet Article 663 of the RCS for individuals who have assigned duties in a tritium facility.

**Prerequisites**

Training which is considered commensurate with site-specific hazards. Radiological Worker II or the equivalent is recommended prior to receiving or concurrently with this tritium facilities safety training. Some of those basic concepts contained in Radiological Worker II are used extensively throughout this training.

**Length**

2 - 4 hours (depending on site-specific information)

**Test Bank**

Test banks, as applicable, should be developed by the sites, incorporating site-specific information.

**Retraining**

Retraining is not required for this course.

**Instructor Qualifications**

Instructors of this course have a major role in making it successful and meeting the specified objectives. Instructors must have related experience and be technically competent. In this course it is imperative that the instructor have the background and experience of working in a tritium facility. Instructors must be able to relate their own work experience to the workers in a tritium facility. Instructors must be able to answer specific questions and use a variety of instructional material to meet the objectives.

Education:

Minimum of B.S. degree in Health Physics or related discipline is <u>preferred</u>.

Experience:

At least five years of applied radiological protection experience in an operating radiological facility is preferred. The areas of experience should include:

-Tritium hazards
-Radiological controls associated with tritium
-Conducting surveys and monitoring for tritium

Comprehensive knowledge of Federal regulations and guidance and best nuclear industry practices pertaining to radiological protection.

**Materials Checklist**

The following checklist should be used to ensure all training materials are available. The Program Management Guide, Instructor's Guide, Student's Guide, and Lessons Learned section are provided in Word 2000 format. The Overhead Transparencies are provided in Power Point 2000 for windows format.

- Program Management Guide
- Instructor's Guide
- Student's Guide
- Overhead Transparencies

The following checklist should be used before training is provided to ensure that equipment is available and working.

- Overhead projector
- Screen
- Flip chart
- Markers

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(Part 2 of 4)

# Radiological Training for Tritium Facilities

# Instructor's Guide

**Coordinated and Conducted**
**for**
**Office of Environment, Safety & Health**
**U.S. Department of Energy**

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**DEPARTMENT OF ENERGY - COURSE PLAN**

Core Course Material

| | |
|---|---|
| Course Goal: | Upon completion of this training the student will have a basic understanding of the characteristics of tritium and understand the precautions and safeguards needed for working in a tritium facility as outlined in the course objectives. |
| Target Audience: | Individuals who have assigned duties in Tritium Facilities. |
| Description: | This course illustrates and reinforces the skills and knowledge needed to provide personnel with an understanding of the characteristics of tritium and the precautions needed for working with or around it in a DOE facility. This course is designed to be consistent with Article 663 of the DOE RSC for individuals who have assigned duties in a tritium facility. |
| Prerequisites: | Training which is considered commensurate with site-specific hazards. Radiological Worker II or the equivalent is recommended prior to receiving or concurrently with this tritium facilities safety training. Some of the basic concepts contained in Radiological Worker II are used extensively throughout this training. |
| Length: | 2 - 4 hours (depending on site-specific information) |

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Course Objectives:

EO1 IDENTIFY the following properties of tritium:
- physical/chemical
- radioactive.

EO2 IDENTIFY sources of tritium:
- natural
- by-product
- weapons.

EO3 IDENTIFY uses of tritium:
- weapons applications
- research
- fusion energy production
- industrial/commercial.

EO4 IDENTIFY modes of tritium exposure:
- inhalation
- ingestion
- absorption
- injection/wound.

EO5 IDENTIFY the biological effects of tritium:
- biological half-life
- dose.

EO6 IDENTIFY the radiological control methods for tritium:
- engineered
- administrative
- surface contamination limits
- personnel protective equipment
- application of ALARA principles.

EO7 IDENTIFY methods for monitoring for tritium:
- air sampling for worker safety
- contamination surveys
- bioassay.

EO8 IDENTIFY tritium waste minimization and handling techniques. (Site-Specific)

E09 IDENTIFY alarms and proper response to abnormal conditions in the tritium facility. (Site-Specific)

| | |
|---|---|
| Training Aids: | Overhead transparencies (may be supplemented or substituted with updated or site-specific information) |
| Equipment Needs: | ○ Overhead projector<br>○ Screen<br>○ Flip chart<br>○ Markers |
| Student Materials: | Students Guide |

## LESSON SUMMARY

| | |
|---|---|
| **Introduction** | |
| Welcome students to the course. | Show Title OT-1 |
| Introduce self and instructor team. | |
| Define logistics. | |
| ○ safety briefing - exits<br>○ restrooms<br>○ hours<br>○ breaks<br>○ sign-in sheets<br>○ test - accountability<br>○ end of course evaluation | |
| Remind the participants that they need to have completed Radiological Worker Training prior to this course. They should be familiar with terms like rem, contamination, etc. | |
| **Course Goal** | |
| At the end of this course, the participant should be able to demonstrate a basic understanding of the characteristics of tritium and precautions for working in a tritium facility as outlined in the course objectives. We will attempt to answer the following questions: | Show OT 2 |
| ○ Tritium, what is it?<br>○ How does it behave?<br>○ What are the benefits and hazards?<br>○ How do we control it? | |
| State Course Objectives | Show OT 3, OT 4, and OT 5 |

**Course Content**

| | |
|---|---|
| Briefly review the content of the course, noting that there is a logical sequence ("flow"), and that as you present the material you will relate the material covered to the circumstances that they can expect to find in the facility workplace and procedures. (You will be inserting site-specific tritium information.) | Show OT 6 |

1. Properties of Tritium
2. Sources and Uses of Tritium
3. Modes of Exposure and Biological Behavior of Tritium
4. Radiological Controls for Tritium
5. Monitoring for Tritium
6. Tritium Waste Minimization and Handling
7. Response to Abnormal Conditions in the Tritium Facility
8. Lessons Learned
9. Summary and Review

| | Notes |
|---|---|
| I. PROPERTIES OF TRITIUM - What is tritium? | Show OT 7 |
| Tritium is a radioactive isotope of hydrogen (H). Hydrogen is the lightest and most abundant element in the universe. Hydrogen has only one proton in its nucleus. Tritium has, in addition to the single proton, two neutrons in its nucleus. This makes it three times heavier than the most common form of hydrogen. | Show OT 8 |
| A. Isotopes of Hydrogen | Show OT 9 |
| 1. Protium (H) (99.985% natural abundance) | |
| 2. Deuterium = hydrogen + 1 neutron (D) (0.015% natural abundance) | |
| 3. Tritium = hydrogen + 2 neutrons (T) | |
| B. Symbol for Tritium | Show OT 10 |
| Tritium is designated as: $T$, $H$-3, or ${}^{3}_{1}H$ | |
| C. Chemical Properties of Hydrogen/Tritium | |
| Tritium "behaves" just like hydrogen chemically because it has one proton and one electron like ordinary hydrogen. | Reaction rates may vary from hydrogen. |

| | Notes |
|---|---|
| 1. Substitution<br><br>Tritium atoms can easily substitute for hydrogen atoms. Examples:<br><br>a. elemental hydrogen (tritium gas, HT, DT, or $T_2$) | Show OT 11 |
| b. tritiated water (tritium oxide: HTO, DTO, or $T_2O$) | Show OT 12 |
| c. organically bound tritium: These compounds may result in more dose per intake than tritiated water. | Show OT 13 - Tritium can replace a loosely bounded hydrogen atom of an organic molecule. |
| d. metals and tritium (metal tritides): These compounds may result in more dose per intake than tritiated water. Accordingly, additional controls may be needed, such as special air monitoring or enhanced personnel protective equipment. | Show OT 14 - Hydride storage of elemental tritium is common. Uranium Hydride is most frequently used for this purpose. Tritium is released by heating the metals to 400 degrees C for 1 atm. dissociation pressure.<br><br>Refer to RCTP 2001-02 and Health Physics Journal September 2001 for more information. |
| 2. Solubility<br><br>Exchanges with hydrogen in organic and other materials (oils, plastics, etc.) | Instructor should emphasize that the biological exchange of tritium with hydrogen in the body is of concern. |
| 3. Flammability<br><br>Tritium gas is flammable and can explode under certain conditions. | Show OT 15 - The range of flammable concentrations of tritium in air is between 4% and 75% by volume in air. |

Notes

D. Physical Properties

1. Diffusion

Tritium gas is lighter than air and diffuses rapidly in air.

Show OT 16

Show OT 17

2. Permeability

Show OT 18

Tritium gas permeates through most materials, that is, it travels through them by way of spaces or interstices in them. The rate depends upon the material and its thickness. Tritium's radioactive, chemically reducing and diffusive properties result in degradation of many useful polymeric materials, pump oils, plastics, and o-rings. This can cause loss of mechanical functions in certain situations within a short period of time.

$^{3}_{1}\text{H}$ decays to $^{3}_{2}\text{He} + \beta^{-} + \overline{\upsilon}$

E. Radioactive Decay of Tritium

$^{3}_{2}He = \ Helium$

$\overline{\upsilon} = anti\text{-}neutrino$

$\beta^{-} = \ beta\ minus$

Show OT 19

Tritium "decays" by emitting a beta particle and becoming an atom of helium.

Notes

1. Beta Energy

A very low energy beta is emitted.

Max energy = 18.6 keV
Ave. energy = 5.7 keV

2. Beta Range

Tritium is not an "external" radiation hazard.

Instructor should emphasize the radiological controls are to keep tritium outside the body. Explain what is meant by "external" radiation hazard.

a. Travels less than 1/4 inch in air

b. Cannot penetrate through the dead layer of the skin

c. Cannot penetrate clothing or gloves

3. Half-life

Show OT 20

Radioactive half-life = 12.3 years.

F. X-Ray Production

Tritium betas can produce low energy x rays. Because the beta particle is of such low energy the x rays it may produce are not very penetrating and are not normally considered a hazard.

Notes

G. Fusion

Fusion is the process of two nuclei joining together. The energy source in most stars is nuclear fusion of hydrogen isotopes.

$${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + {}^{1}_{0}n$$

1 mev per fusion

Show OT 21

$${}^{3}_{1}H + {}^{2}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$$

17 mev per fusion

SOURCES AND USES OF TRITIUM

Show OT 22

How is tritium produced and what is it used for?

Show OT 23

A. Sources of Tritium

Modes of production:

There are three primary sources of tritium in our environment. Tritium is present in our environment from both man-made and natural sources as discussed below. Natural tritium is indistinguishable from man-made tritium.

1. The nitrogen nucleus captures a neutron and decays to tritium and carbon.

$${}^{14}_{7}N + {}^{1}_{0}n \text{ yields}$$
$${}^{3}_{1}H + {}^{12}_{6}C$$

1. Natural Sources

Tritium occurs naturally. It is formed by the reactions between cosmic rays and the nitrogen in the upper atmosphere. Nitrogen makes up 80% of the earths atmosphere.

Cosmic rays generate approximately 4 million curies of tritium per year. With tritium being continually produced and at the same time decaying, the natural tritium in our environment is about 70 million curies.

$${}^{2}_{1}H + {}^{2}_{1}H \text{ yields}$$
$${}^{3}_{1}H + {}^{1}_{1}H$$

2. Two hydrogen-2 atoms (deuterium) combine to form tritium and normal hydrogen.

| | Notes |
|---|---|
| 2. By-Product of Reactor Sources | ${}^{7}_{3}\mathrm{Li} + {}^{1}_{0}\mathrm{n}$ yields ${}^{3}_{1}\mathrm{H} + {}^{1}_{0}\mathrm{n} + \alpha$<br>${}^{10}_{5}\mathrm{B} + {}^{1}_{0}\mathrm{n}$ yields ${}^{3}_{1}\mathrm{H} + 2\alpha$ |
| a. Lithium-7 captures a neutron and decays with tritium as a product. | |
| b. Boron captures a neutron and decays with tritium as a product. | Show OT 24<br>${}^{2}_{1}\mathrm{H} + {}^{1}_{0}\mathrm{n}$ yields ${}^{3}_{1}\mathrm{H}$ |
| c. Activation of deuterium in water. | |
| d. Ternary fission - A fission resulting in three fission products, one of which is tritium. This process has a 0.1% yield. | |
| The production of tritium from power reactors around the world is less than one-half that naturally formed (approximately 1 to 2 million curies a year). | |
| 3. Weapons Testing as a Source | Show OT 25 |
| The amount of tritium in the world from weapons testing has been steadily declining since the 1970's when atmospheric testing was curtailed. | |
| Atmospheric testing from 1945-1975 produced about 8 billion curies. This has decayed to about 400 million curies. | |

| | | Notes |
|---|---|---|
| | 4. DOE Production of Tritium<br><br>DOE has produced tritium at the Savannah River Site with the use of a reactor. Tritium is commercially available from from Canada and the European Community for non-weapons use. | ${}^{6}_{3}\mathrm{Li} + {}^{1}_{0}\mathrm{n}$ yields ${}^{3}_{1}\mathrm{H} + \alpha$ |
| B. | Uses of Tritium | Show OT 26 |
| | 1. Consumer Products<br><br>a. <u>Gaseous tritium light sources</u><br>○ exit signs (1 Ci to tens of Ci's)<br>○ aviation landing aids (30-165 Ci per light)<br>(1 curie of tritium has a mass of approximately 0.1 mg)<br><br>b. <u>Luminizing industry</u>: Self-luminous compounds for dials (several mCi's) and controls as well as other general industry uses. | Instructor - emphasize that tritium has use in everyday activities.<br><br>Approximately 100,000 Ci per runway |
| | 2. Research - Tritium Labeling<br><br>Tracers for medical and laboratory research. | Show OT 27 |
| | 3. Department of Energy<br><br>a. <u>Weapons development and applications</u><br><br>b. <u>Fusion energy</u>: As a fuel source | Show OT 28 |

| | Notes |
|---|---|
| III. MODES OF EXPOSURE AND BIOLOGICAL BEHAVIOR OF TRITIUM - How can I be exposed to tritium and what would it do to me? | Show OT 29 |
| A. External Dose<br><br>◦ Tritium is not an external hazard.<br>◦ Tritium is not a dose concern if it is located outside the body.<br>◦ Tritium betas will not penetrate a dosimeter.<br>◦ We are interested only in tritium inside the body. | Show OT 30<br><br>The tritium beta when it is stopped (particularly in high atomic numbered materials, e.g., lead) will produce a low energy x-ray. This x-ray cannot penetrate into the body, because of the low energy of the x-ray.<br><br>There may be rare circumstances where external dose should be considered (i.e., using large quantities of tritium). |
| B. Internal Dose<br><br>Tritium is an "internal" radiation hazard. | |
| C. Modes of Exposure<br><br>Tritium can deliver a radiation dose if it gets inside our bodies. Modes of entry include:<br>◦ inhalation<br>◦ absorption<br>◦ injection (cuts/wounds)<br>◦ ingestion | Show OT 31 |

Notes

1. Inhalation

Show OT 32

a. Tritium gas: is only slightly incorporated into the body when inhaled. Most tritium gas inhaled is subsequently exhaled. There are other chemical and physical processes to convert tritium gas to tritiated water.

An extremely low percent (in the order of 0.005%) of tritium gas inhaled is converted to tritiated water prior to being exhaled.

b. Tritiated water vapor: Nearly 100% of tritiated water vapor inhaled is incorporated into body fluids/tissues.

Tritiated water vapor is more hazardous due to its ability to be almost 100% assimilated, increasing the dose received by the individual.

c. Hazard: Exposure to tritiated water is approximately 25,000 times more hazardous than exposure to elemental tritium gas.

d. Special Tritium Compounds: consist of organically bound tritium and tritium particulate aerosols.

Exposure to organically bound tritium can be up to approximately 13 times more hazardous than exposure to HTO.

Refer to RCTP 2001-02 and Health Physics Journal September 2001.

Exposure to tritium particulate aerosols can deliver up to approximately 20 times more dose to the whole body than exposure to HTO. The dose to the lungs from tritium particulate aerosols could be 2 orders of magnitude higher than from HTO.

2. Ingestion

***Ingestion*** may occur by eating, drinking, chewing tobacco, and applying makeup where tritium contamination is present. Always wash hands thoroughly when leaving areas where there is a potential for contamination, and never eat, drink etc. where tritium contamination may be present.

Notes

3. Absorption

Show OT 33

Absorption is also a hazard because an individual can receive, in certain situations, 1/3 of their uptake from absorption through the skin if not properly using personal protective equipment.

The assumption is that an additional 50% of the inhalation intake is absorbed through the skin.

a. Tritium gas: There is negligible skin absorption for tritium gas.

b. Tritiated water: Tritiated water can be absorbed through the skin. It has been observed that moisture on hands enhances absorption.

This is an important fact for maintenance workers to know.

c. Solvents: Some solvents (organically bound tritium) can also go through the skin.

Insert site specific information concerning gloves.

Tritium will penetrate gloves, therefore gloves must be changed at a prescribed routine basis.

D. Biological Behavior of Uptakes of Tritium

Tritiated water in the body acts just like water.

1. Distribution

Show OT 34

Tritiated water is rapidly and uniformly distributed throughout the entire body. The Committed Effective Dose Equivalent (CEDE) from an uptake of one curie of tritiated water is 63 rem. Soluble organically bound tritium behaves in the body in a similar manner.

Typical production reactor coolant has approximately 10 Ci/L of tritium. So 100 ml of such coolant has about 1 Ci of tritium. If approximately 8 ml was ingested a CEDE of 5 rem (the annual limit) would result.

Stable tritium particulate aerosols and insoluble organically bound tritium behave in the body in a similar manner as the particulate to which the tritium is bound.

| | Notes |
|---|---|
| 2. Biological Half-life | Show OT 35 |
| Half of the HTO is eliminated from the body in about 10 days. Through normal biological processes, it would take 70 days or more to eliminate 99% of the assimilated tritiated water. | |
| Stable tritium particulate aerosols and insoluble organically bound tritium behave in the body in a similar manner as the particulate to which the tritium is bound and would have a longer half life. | |
| E. Medical Treatment | Show OT 36 |
| The biological half-life can be shortened by increasing the water elimination in the body. Therefore, individuals who have uptakes of tritium are encouraged to drink water. Drinking copious amounts of water should not be done without a physician's guidance. Certain medical conditions may be affected by liquid intake. | Insert site-specific policy. |
| IV. RADIOLOGICAL CONTROLS FOR TRITIUM - How can I protect myself from exposures to tritium? | Show OT 37 |
| Tritium can be present in a variety of chemical forms. Ongoing research indicates that the form of tritium which gives the highest dose (per unit intake) is tritium particulate aerosols. However, these compounds are not found in the quantities and various locations as tritiated water. If we can rule out special tritium compounds as being of concern, we assume it may be tritiated water. | Show OT 38 |
| The preferred hierarchy of control is as follows:<br>◦ engineered<br>◦ administrative<br>◦ personal protective equipment | |

| | Notes |
|---|---|
| A. Engineered Controls | Show OT 39 |
| 1. Containment and Confinement | |
| Containment or confinement is a series of physical barriers, minimizes exposure of workers. | |
| Confinements such as glove boxes are almost always used when handling large quantities of tritium. However, hoods are acceptable for handling small quantities, such as in a laboratory. | Instructor should insert site specific information concerning what is considered large or small quantities for handling tritium. |
| 2. Airflow | Show OT 40 |
| Maintaining negative ventilation is essential for the safe operation of a tritium facility. Airflow should be from areas of LEAST to MOST contamination. | May need to use site specific terminology. |
| 3. Local Exhaust Ventilation | |
| The primary advantage of local exhaust ventilation techniques is the removal of airborne tritium, regardless of its release rate or chemical or physical form. In addition, these techniques use relatively low volume rates compared to normal ventilation requirements. | |

Notes

4. Dilution Ventilation

Dilution ventilation is the once-through flow technique of exchanging outside air for inside air for comfort and the reduction of airborne sources.

Tritium is considered valuable and needs to be recovered. (i.e. not to send up the stack)

5. Storage

Tritium can be stored in storage beds. Metal tritide and uranium hydride are the most common for these storage systems. Tritium is generally released by heating the metal tritide.

B. Administrative Controls

Show OT 41

There are many administrative controls to reduce doses. The following are just a few that should apply to all sites:

- limitation of access time
- procedures/RWPs
- postings

Ask students to name other ways to prevent or reduce doses.
Insert site specific posting requirements.

For tritium and tritium compounds, 10 CFR 835 Appendix D requires posting contamination areas based on removable contamination values of 10,000 dpm/100cm$^2$.

| | Notes |
|---|---|
| C. Personal Protective Equipment | Show OT 42 |
| 1. Air Supplied Suits | |
| Because of the absorption through the skin associated with the use of respirators and other breathing apparatus, air-supplied plastic suits that completely enclose the body are widely used by facilities that handle large quantities of tritium. | |
| 2. Protective Clothing | Discuss site specific requirements |
| Protective clothing (PC), or anti-contamination clothing (anti-Cs), is used to minimize the spread of contamination from contaminated to clean areas. | |
| In many operations, the hands and forearms of workers are vulnerable to contact with tritium surface contamination. The proper selection of gloves and glove materials is important. In many instances a plastic/water proof suit is required. | Insert site specific information concerning selection of PCS. Even with a plastic or water-proof PC suit, a stay time may be assigned due to the ability of tritium to permeate through plastic. |
| V. MONITORING FOR TRITIUM - How do I know if tritium is present? | Show OT 43 |

| | Notes |
|---|---|
| A. Personnel Monitoring | Show OT 44 |
| 1. External Dose<br><br>Dosimeters are not typically used to monitor for radiological doses resulting from tritium. The weak energy beta radiation will not penetrate the dosimeter.<br><br>(insert any site specific monitoring procedures) | Insert site specific requirements |
| 2. Internal Dose | |
| The best method used to determine if an individual has an uptake of HTO or soluble organically bound tritium is by bioassay (urinalysis). Routine urine samples, collected at some predetermined frequency and counted for the tritium content, provide a very sensitive measurement of tritium in the body. This is especially true if the time of uptake is known.<br><br>Air sampling results may be used to assess dose from other types of special tritium compounds. | Show OT 45 |
| 3. Routine Versus Non-Routine Bioassay Monitoring<br><br>a. Routine: Routine urinalysis is conducted on a preset periodic basis.<br><br>b. Non-routine or Special: Non-routine bioassay is done whenever a potential exposure to tritium is suspected.<br><br>(insert site specific bioassay procedures) | 1. Prospective: Prospective bioassay is routine bioassay. |

| | Notes |
|---|---|
| B. Workplace Monitoring | Show OT 46 |
| Air monitoring and surface contamination surveys are used to verify that loose contamination is not present. They provide an early indication of potential problems. | |
| 1. Airborne Tritium Monitoring | Show OT 47 |
| Airborne tritium monitoring is used for: | Insert and discuss site specific information concerning equipment. |
| a. Prompt detection of airborne contamination for worker protection; | |
| b. Determination of the status of processes; and | |
| c. Identification of any leaks in primary or secondary containments or confinements. | |
| 2. Contamination Surveys | |
| Despite contamination control measures, tritium is easily spread. | Show OT 48 |
| All workplaces shall be surveyed for contamination levels on a regularly scheduled basis. The frequency of such surveys will depend on the potential for dispersement of the tritium-contaminated material in the area and the quantity of tritium in the area. During routine surveys, all work enclosures, work surfaces, floors, equipment, etc., within the workplace should be surveyed. | |

Notes

At the surface contamination levels in 10 CFR 835 Appendix d, tritium is difficult to measure directly because the low-energy beta is readily absorbed in air and the window of the detector. Normal frisking methods (use of pancake probe) will not detect tritiated water.

Show OT 49

Surfaces are normally wiped (smeared) with a small paper, either dry or moistened, which will pick up loose tritiated material. The wipe is then normally counted by liquid scintillation techniques.

VI. TRITIUM WASTE MINIMIZATION AND HANDLING- Why is it important and how do you minimize tritium waste?

Show OT 50

This material maybe covered in Radiological Worker I or II training. Emphasis should be on site specific information. It is not necessary to repeat information.

(insert site specific controls)

Methods below are given as a reference only.

A. Minimizing Tritium-Contaminated Waste

1. Avoid generating wastes by not bringing unnecessary material into the controlled area.

2. Whenever possible, avoid use of porous materials or those known to be highly permeable to tritium.

3. Designate an area to store contaminated tools for reuse or consider all tools in the area to be contaminated.

Notes

4. Plan work so that, whenever possible, construction and clean maintenance can be done in a clean area.

5. When transporting items contaminated with tritium, adequate contamination control such as wrapping in plastic or placing in sealed containers should be considered.

Insert site-specific information concerning procedures for transporting tritium contaminated items.

B. Minimizing Mixed Waste

(insert site specific controls)

Methods below are given as a reference only.

1. Use non-hazardous cleaning materials for decontamination whenever possible.

2. Segregate radioactive-only from hazardous-only at the source.

3. Explore the use of other materials which are non-hazardous for use in radiological areas to prevent the generation of mixed waste.

VII. RESPONSE TO ABNORMAL CONDITIONS IN THE TRITIUM FACILITY- What should I do in an emergency involving tritium?

To properly deal with unexpected adverse situations occurring in a tritium facility, a well-thought-out response program and personnel trained to execute the response should be in place.

Show OT 51
This material may be covered in Radiological Worker I or II training. Emphasis should be on site specific information. It is not necessary to repeat information.

| | | Notes |
|---|---|---|
| | A. Abnormal Conditions | |
| | Abnormal conditions in a tritium facility could include:<br>○ fire/explosion<br>○ natural disaster<br>○ tritium releases<br>○ other hazards | |
| | Personnel found contaminated should follow site specific decontamination procedures which would typically include showering with cold water and the use of mild detergents. | |
| | B. Facility Alarms | |
| | (insert site specific alarms and emergency response procedures) | |
| | C. Facility Emergency Responses | Insert site specific emergency plan and hazards assessment documents. |
| | (insert site specific alarms and emergency response procedures) | |
| VIII. | LESSONS LEARNED | Show OT 52 |
| | (insert site specific lessons learned) | |
| IX. | SUMMARY AND REVIEW | Show OT 53 |

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(Part 3 of 4)

# Radiological Training for Tritium Facilities

# Overheads

**Coordinated and Conducted**
**for**
**Office of Environment, Safety & Health**
**U.S. Department of Energy**

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# Radiological Training for Tritium Facilities

## Overhead Transparencies

- Tritium - what is it?
- How does it behave?
- What are the benefits and hazards?
- How do we control it?

# Radiological Training for Tritium Facilities

## Objectives

1. **IDENTIFY the following properties of tritium**
   - **physical/chemical**
   - **radioactivity**

2. **IDENTIFY sources of tritium**
   - **natural**
   - **by-product**
   - **weapons**

3. **IDENTIFY uses of tritium**
   - **weapons applications**
   - **research**
   - **fusion energy production**
   - **industrial/commercial**

# Objectives

(Continued)

4 IDENTIFY modes of tritium exposure
- inhalation
- ingestion
- absorption
- injection/wounds

5 IDENTIFY biological effects of tritium
- dose
- biological half-life

6 IDENTIFY radiological control methods for tritium
- engineered
- surface contamination limits
- personal protective equipment
- application of ALARA principles
- administrative

# Objectives

**(Continued)**

7. **IDENTIFY methods for monitoring tritium**
   - **air sampling for worker safety**
   - **contamination surveys**
   - **bioassay**

8. **IDENTIFY tritium waste minimization and handling procedures**

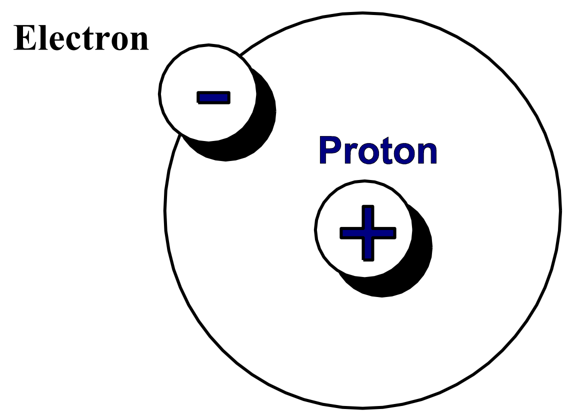
9. **IDENTIFY alarms and proper response to abnormal conditions in the tritium facility**

# Outline

1. Properties of tritium
2. Sources and uses of tritium
3. Modes of exposure and biological effects of tritium
4. Radiological controls for tritium
5. Monitoring for tritium
6. Tritium waste minimization and handling
7. Response to abnormal condition in the tritium facility
8. Lessons learned
9. Summary and Review

# What is Tritium?
# Properties of Tritium
## H-3

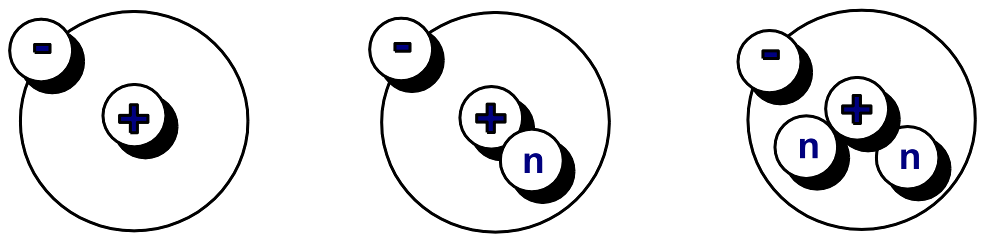
# All hydrogen atoms have one proton (H)



# The number of neutrons may vary

## ISOTOPES of hydrogen

| Protium H | Deuterium D | Tritium T |
|---|---|---|

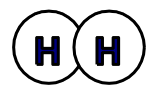



| No neutrons | 1 neutron | 2 neutrons |
|---|---|---|
| **H** | **D** | **T** |

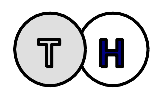
**Tritium is designated as:**

**T or H-3 or $^{3}_{1}H$**

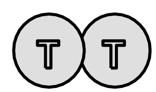
# Tritium can easily substitute for protium (H)

Normal Hydrogen Gas  $H_2$



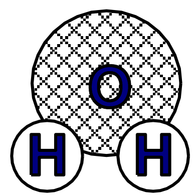
Tritiated Gas  HT



Tritium Gas  TT or $T_2$

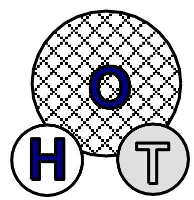
# Tritium behaves just like hydrogen

Normal Water




$H_2O$

Tritiated Water



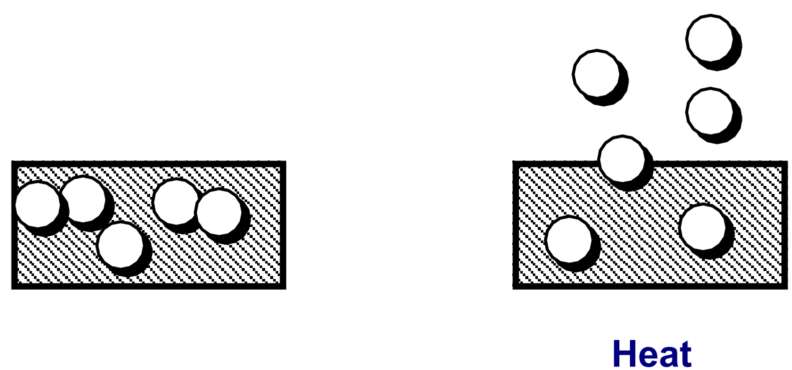

HTO

# Tritium can form organic compounds

$C_6H_{12}+T_2$ "Benzene" $\rightarrow C_6H_{11}T+HT$ or

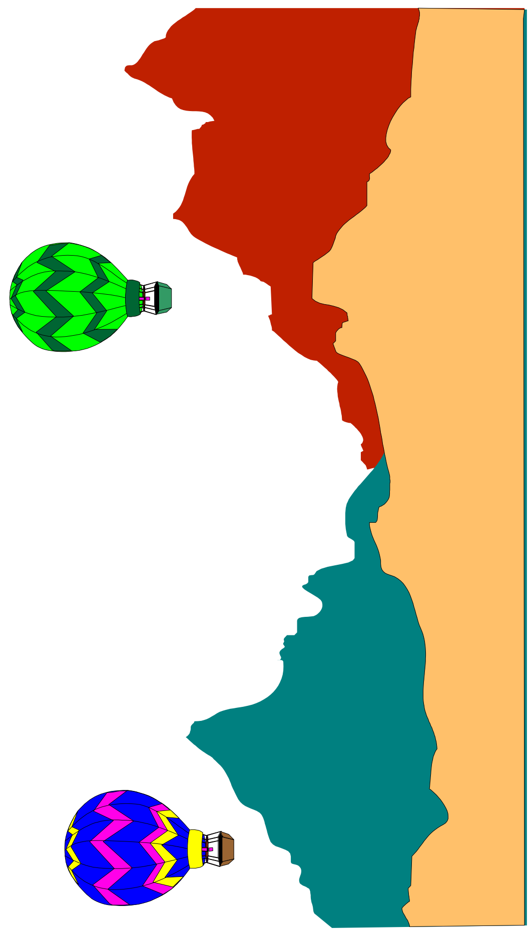
$CH_4+T_2$ "Methane" $\rightarrow CH_3T+HT$

# Tritium can be captured in metallic compounds called "Hydrides" and then released by heating

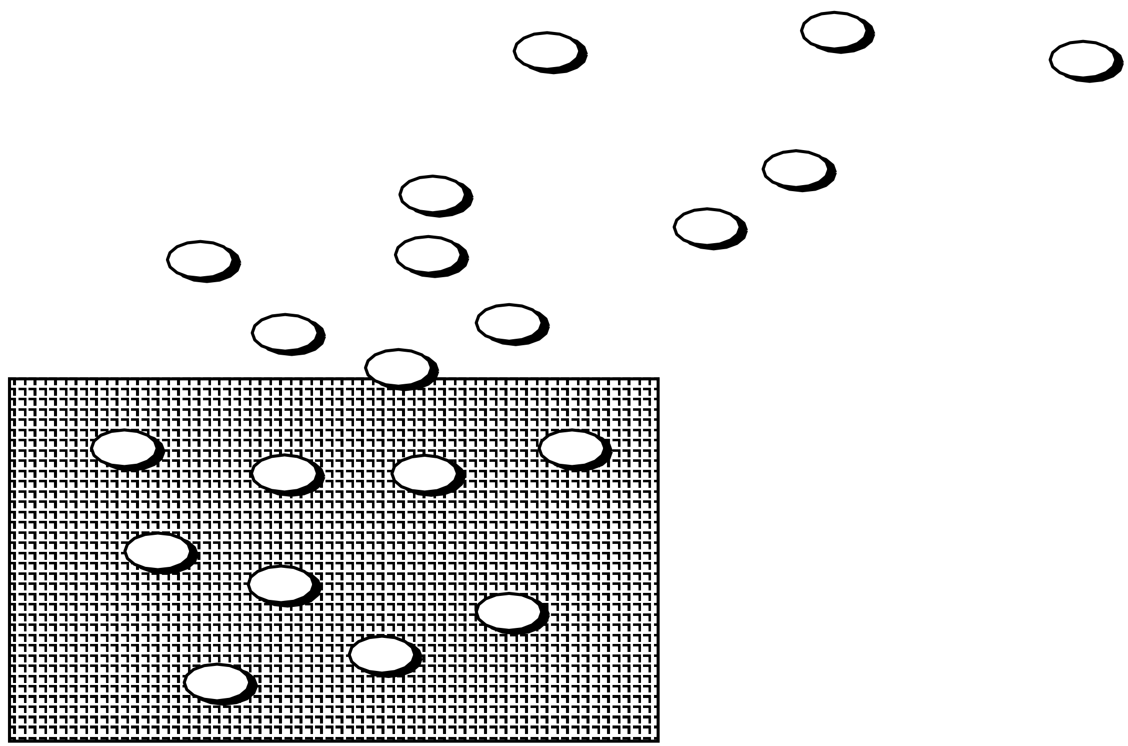


# Hydrogen/tritium gas may be flammable

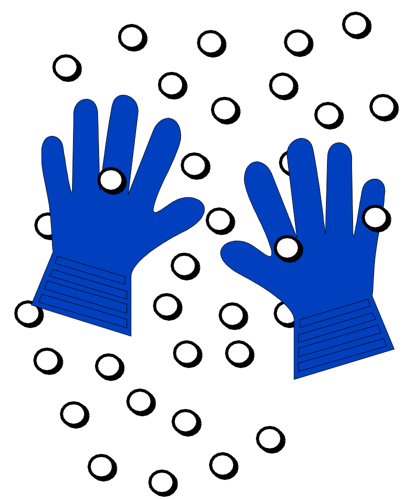
# Hydrogen/tritium gas is lighter than air



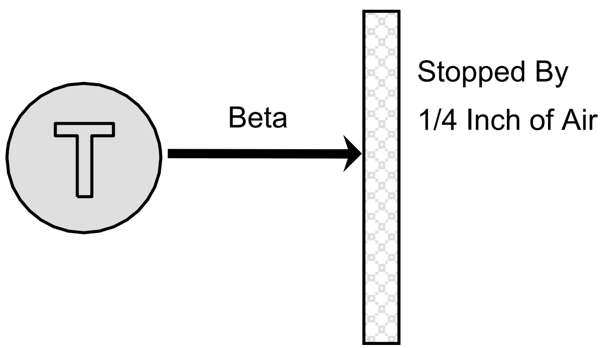
# Hydrogen/tritium gas rapidly disperses in air



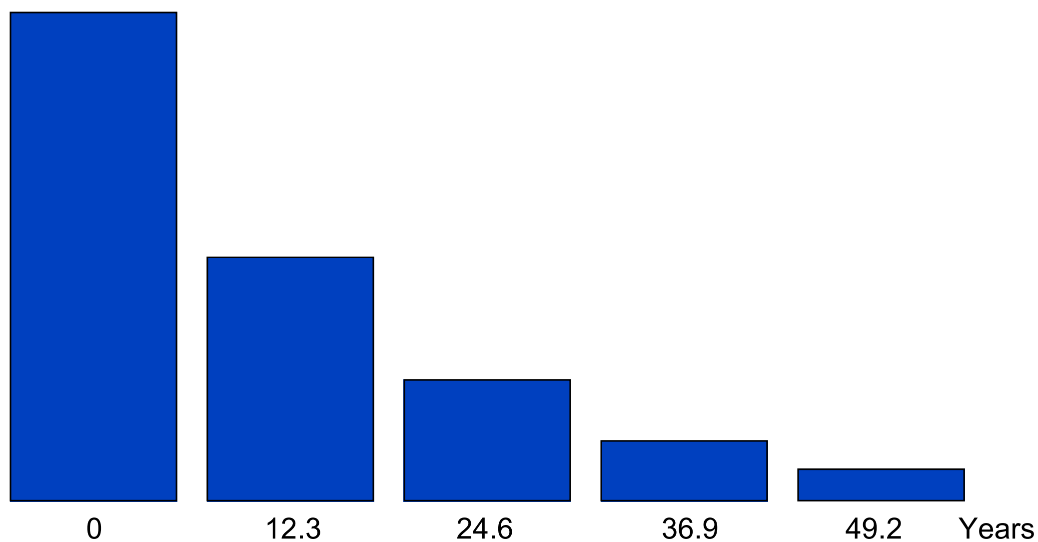
# Hydrogen/tritium gas and tritiated water penetrates through most materials, including gloves



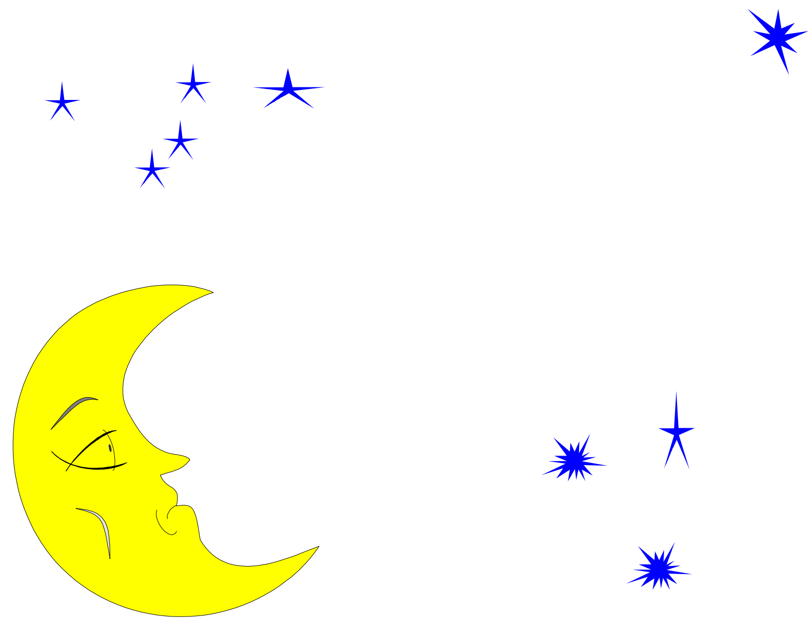
# Tritium decays by emitting a weak beta particle



# The radioactive half-life of tritium is 12.3 years



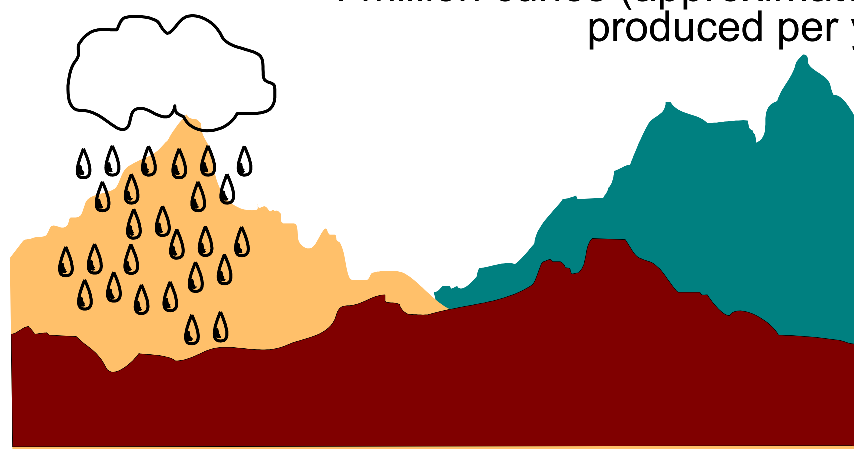
# Fusion of hydrogen and other light element isotopes fuels the stars



# Sources of Tritium

# Tritium is produced naturally by cosmic rays and is carried to the earth's surface by rain

4 million curies (approximately 0.41 kg) produced per year



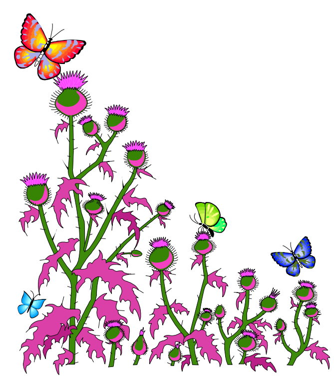
**World inventory of natural tritium from cosmic ray interactions is approximately 70 million curies.**

# Tritium is formed in reactors by ternary fission and activation of light elements

Commercial production - 1 million curies per year

Nuclear reactors - 1-2 million curies per year

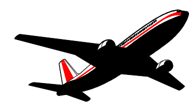
# Environmental tritium from atmospheric testing will be at natural levels by about 2030

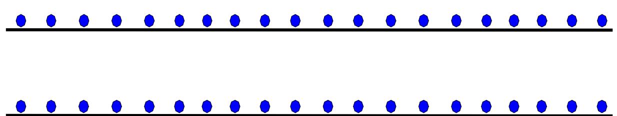


The world inventory of tritium from atmospheric testing is approximately 400 million curies (approximately 41 kg).

# Tritium is used commercially in a variety of products

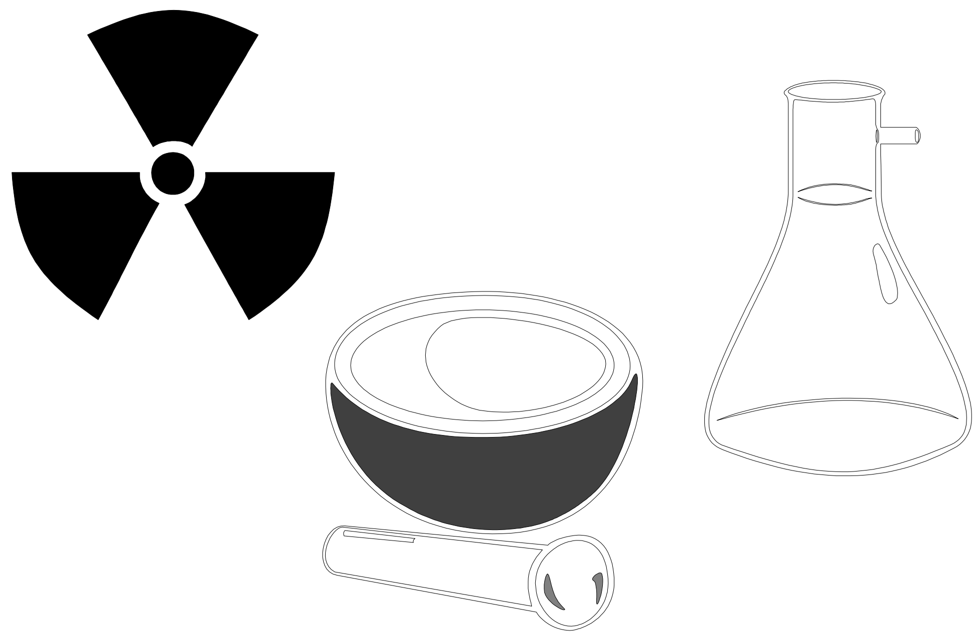

Illuminating Signs





Runway Lights

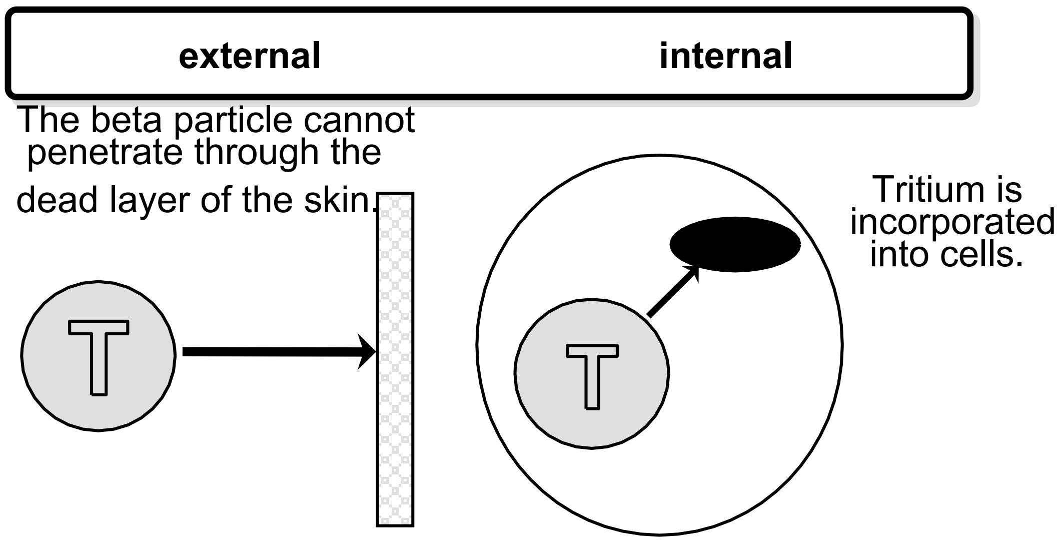
# Tritium is used extensively in biology and medical research



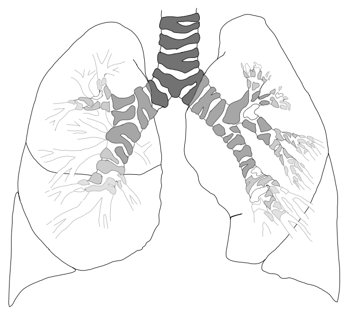
# Tritium is the fuel in fusion reactions

# Modes of Exposure and Biological Behavior of Tritium

## Tritium is NOT an external radiation hazard-It is an internal hazard when taken into the body



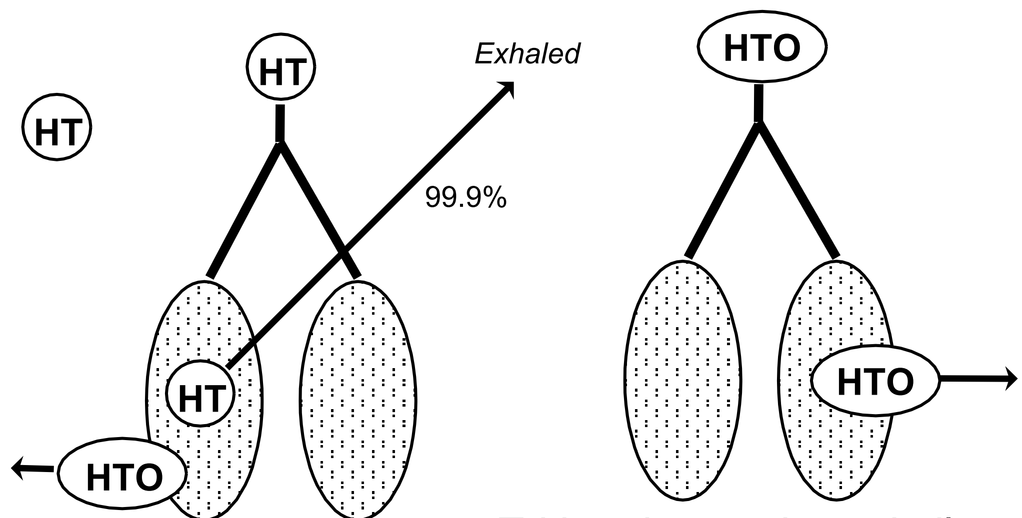
# The main pathways for uptake of tritium are:



Inhalation

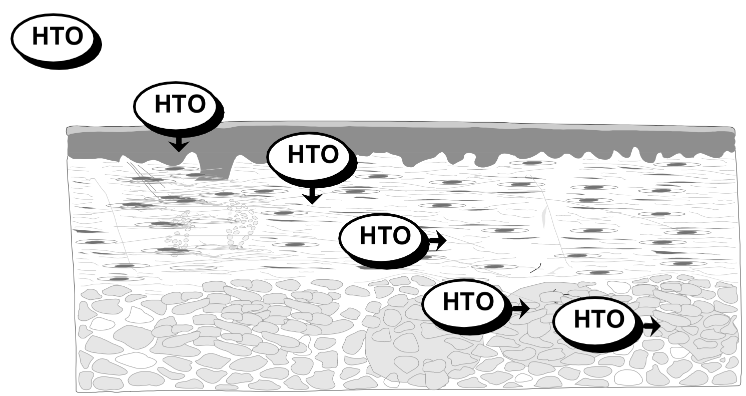
Absorption

**Tritiated water vapor is more hazardous than tritium gas, as it is readily incorporated into the body**

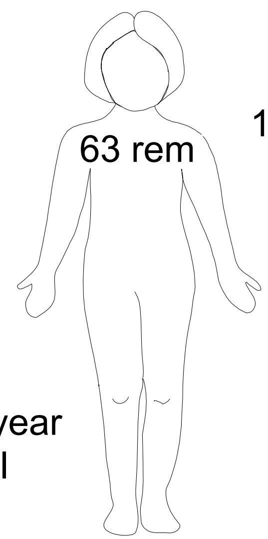



Tritiated water is assimilated in the body 20,000 times more than tritium gas

# Tritiated water can also be absorbed through skin into body water.



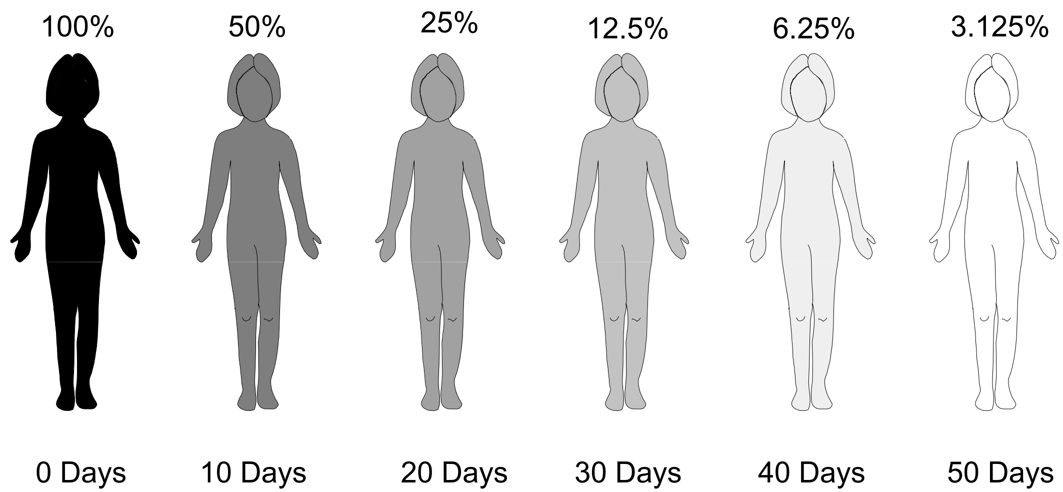
# Tritium taken into the body is distributed throughout the body.



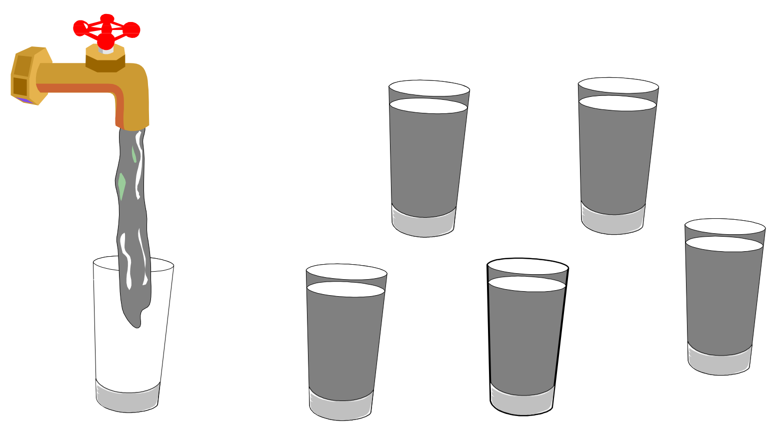

1 Curie of tritiated water

10CFR835
establishes 5 rem/year
as the occupational
dose limit.

# The biological half-life of tritium is about 10 days.

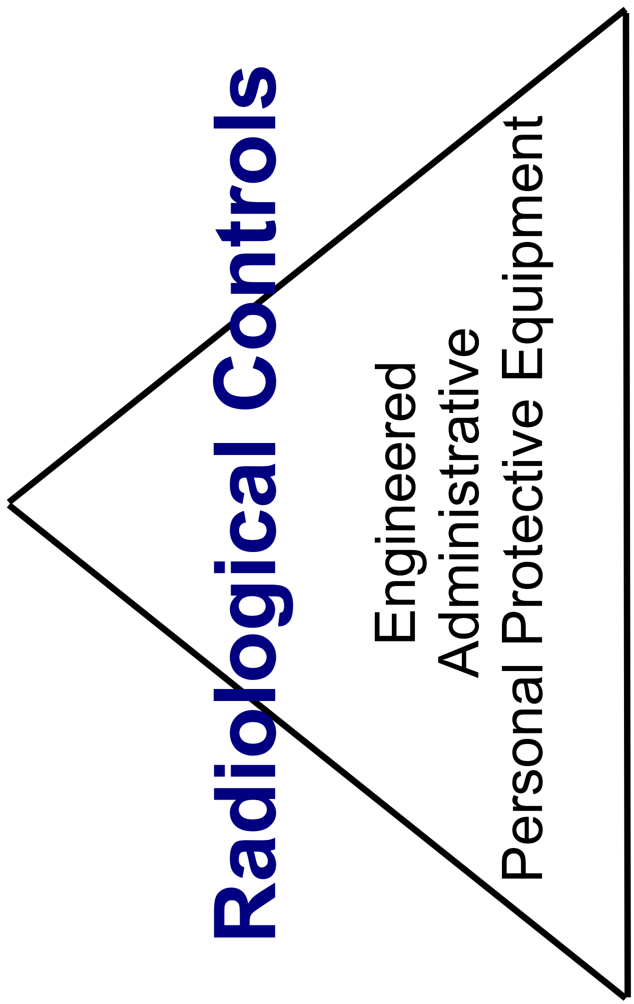


**The elimination of tritium from the body can be increased by increasing water intake**



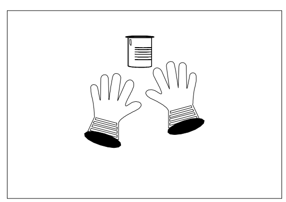
**However, this should only be performed under medical supervision**

# Radiological Controls



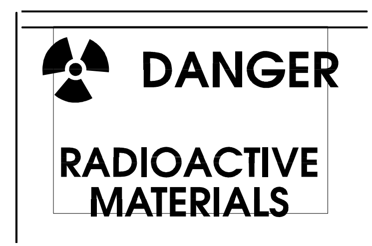
# Engineered controls are preferred over administrative ones.

**Engineered**

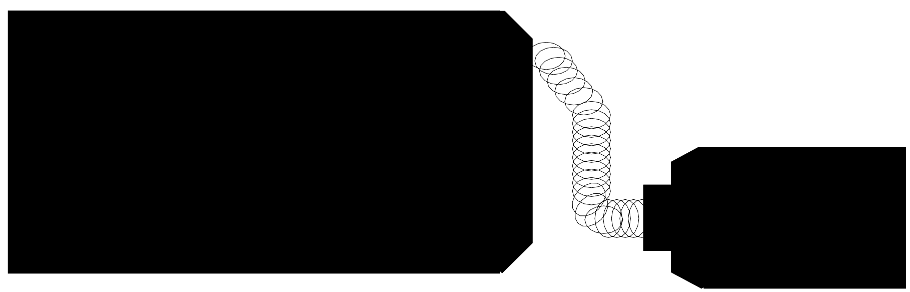


Glovebox

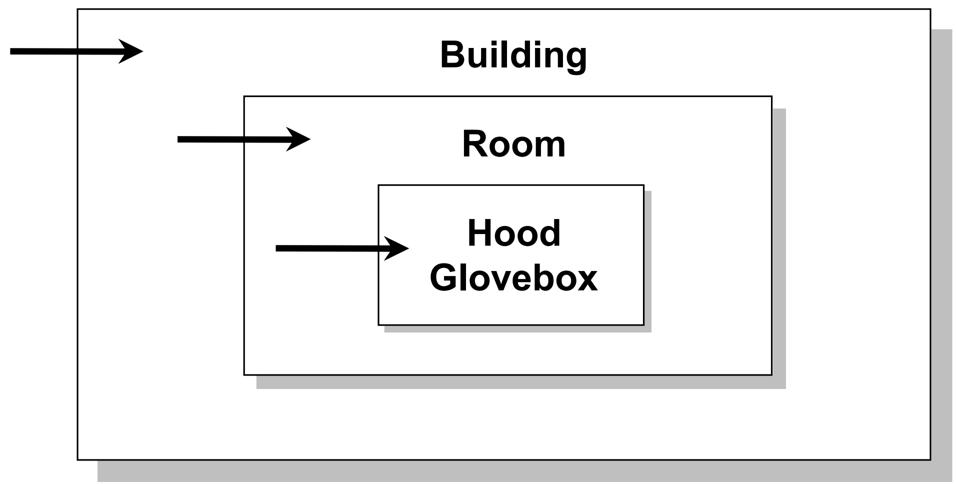
**Administrative**



**Larger quantities of tritium are handled in engineered containment systems.**

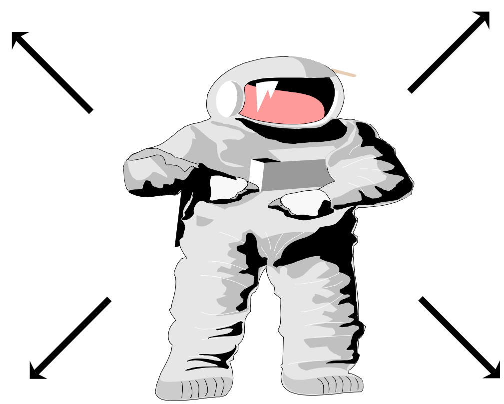


# Airflow should be from areas of LEAST to MOST contamination in tritium facilities



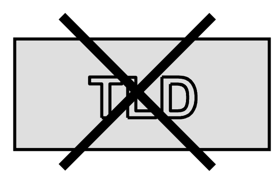
**Access controls may also be administrative.**

**Because of the permeability of tritium, large quantities must be handled using air supplied suits.**

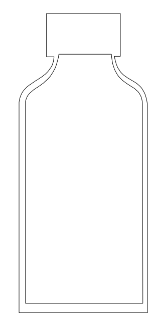


# Monitoring for Tritium

# Your dosimeter is NOT used to monitor tritium dose which results from assimilation of tritiated water in the body.



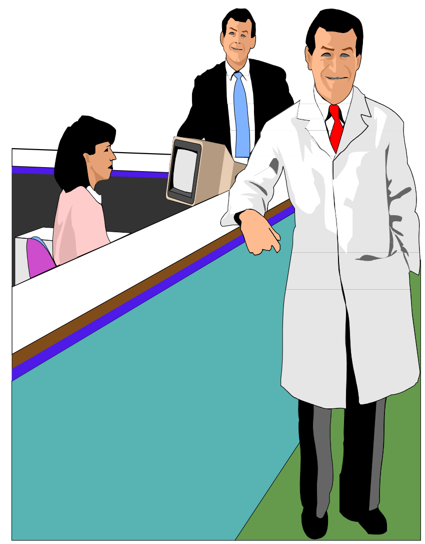

TLDs are used for external exposure.  Tritium betas cannot penetrate the TLD case.



Bioassay is used to determine tritium dose.

# Urinalysis is used to monitor for possible uptakes of tritium.

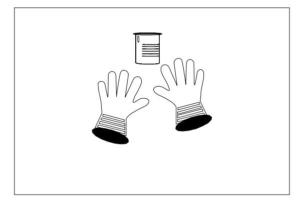
Both: Routine and
Non-Routine



# Workplace monitoring for tritium

**Monitor**

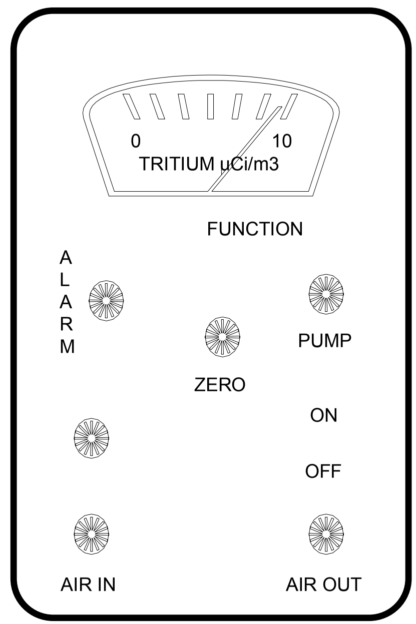
**Swipes**



Glovebox

Personal Air Sampler

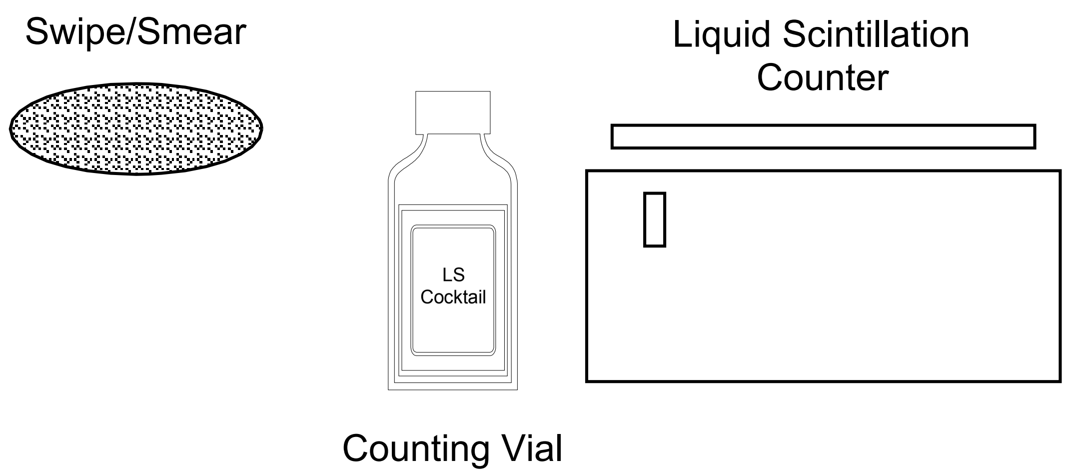
# Area fixed air monitors and tritium sniffers are used to detect tritium leaks/releases.



# Tritium spreads easily, therefore contamination control requires constant vigilance.

*Tritium is like sand at the beach...*
*It gets into everything!*

# Tritium contamination is detected and measured by taking swipes/smears.



# Tritium Waste Minimization and Handling

- Avoid generating waste by not bringing unnecessary material into the controlled area.
- Whenever possible, avoid use of porous materials or those known to be highly permeable to tritium.
- Designate an area to store contaminated tools for reuse.
- Plan work so that, whenever possible, construction and clean maintenance can be done in a clean area.

# Response to Abnormal Conditions

# Lessons Learned

# Summary and Review

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(Part 4 of 4)

# Radiological Training for Tritium Facilities

## Student's Guide

**Coordinated and Conducted**
**for**
**Office of Environment, Safety & Health**
**U.S. Department of Energy**

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Course Objectives:

EO1 IDENTIFY the following properties of tritium:
- physical/chemical
- radioactive.

EO2 IDENTIFY sources of tritium:
- natural
- by-product
- weapons.

EO3 IDENTIFY uses of tritium:
- weapons applications
- research
- fusion energy production
- industrial/commercial.

EO4 IDENTIFY modes of tritium exposure:
- inhalation
- ingestion
- absorption
- injection/wound.

EO5 IDENTIFY the biological effects of tritium:
- biological half-life
- dose.

EO6 IDENTIFY the radiological control methods for tritium:
- engineered
- administrative
- surface contamination limits
- personnel protective equipment
- application of ALARA principles.

EO7 IDENTIFY methods for monitoring for tritium:
- air sampling for worker safety
- contamination surveys
- bioassay.

EO8 IDENTIFY tritium waste minimization and handling techniques. (Site-Specific)

E09 IDENTIFY alarms and proper response to abnormal conditions in the tritium facility. (Site-Specific)

Notes

I. PROPERTIES OF TRITIUM - What is tritium?

Tritium is a radioactive isotope of hydrogen (H). Hydrogen is the lightest and most abundant element in the universe. Hydrogen has only one proton in its nucleus. Tritium has, in addition to the single proton, two neutrons in its nucleus. This makes it three times heavier than the most common form of hydrogen.

A. Isotopes of Hydrogen

1. Protium (H) (99.985% natural abundance)
2. Deuterium = hydrogen + 1 neutron (D) (0.015% natural abundance)
3. Tritium = hydrogen + 2 neutrons (T)

B. Symbol for Tritium

Tritium is designated as:

$$\mathrm{T,\ H\text{-}3,\ or\ }{}^{3}_{1}\mathrm{H}$$

C. Chemical Properties of Hydrogen/Tritium

Tritium "behaves" just like hydrogen chemically because it has one proton and one electron like ordinary hydrogen.

Notes

1. Substitution

   Tritium atoms can easily substitute for hydrogen atoms. Examples:

   a. elemental hydrogen (tritium gas, HT, DT, or $T_2$)

   b. tritiated water (tritium oxide: HTO, DTO, or $T_2O$)

   c. organically bound tritium: These compounds may result in more dose per intake than tritiated water.

   d. metals and tritium (metal tritides): These compounds may result in more dose per intake than tritiated water. Accordingly, additional controls may be needed, such as special air monitoring or enhanced personnel protective equipment.

2. Solubility

   Exchanges with hydrogen in organic and other materials (oils, plastics, etc.)

3. Flammability

   Tritium gas is flammable and can explode under certain conditions.

Notes

D. Physical Properties

1. Diffusion

Tritium gas is lighter than air and diffuses rapidly in air.

2. Permeability

Tritium gas permeates through most materials, that is, it travels through them by way of spaces or interstices in them. The rate depends upon the material and its thickness. Tritium's radioactive, chemically reducing and diffusive properties result in degradation of many useful polymeric materials, pump oils, plastics, and o-rings. This can cause loss of mechanical functions in certain situations within a short period of time.

$^{3}_{1}\text{H}$ decays to $^{3}_{2}\text{He} + \beta^{-} + \overline{\upsilon}$

E. Radioactive Decay of Tritium

$$^{3}_{2}He = \textit{Helium}$$
$$\overline{\upsilon} = \textit{anti-neutrino}$$
$$\beta^{-} = \textit{beta minus}$$

Tritium "decays" by emitting a beta particle and becoming an atom of helium.

Notes

1. Beta Energy

   A very low energy beta is emitted.

2. Beta Range

   Tritium is not an "external" radiation hazard.

   a. Travels less than 1/4 inch in air

   b. Cannot penetrate through the dead layer of the skin

   c. Cannot penetrate clothing or gloves

3. Half-life

   Radioactive half-life = 12.3 years.

F. X-Ray Production

Tritium betas can produce low energy x rays. Because the beta particle is of such low energy the x rays it may produce are not very penetrating and are not normally considered a hazard.

Notes

G. Fusion

Fusion is the process of two nuclei joining together. The energy source in most stars is nuclear fusion of hydrogen isotopes.

SOURCES AND USES OF TRITIUM

How is tritium produced and what is it used for?

A. Sources of Tritium

There are three primary sources of tritium in our environment. Tritium is present in our environment from both man-made and natural sources as discussed below. Natural tritium is indistinguishable from man-made tritium.

1. Natural Sources

Tritium occurs naturally. It is formed by the reactions between cosmic rays and the nitrogen in the upper atmosphere. Nitrogen makes up 80% of the earths atmosphere.

Cosmic rays generate approximately 4 million curies of tritium per year. With tritium being continually produced and at the same time decaying, the natural tritium in our environment is about 70 million curies.

Notes

2. By-Product of Reactor Sources

   a. Lithium-7 captures a neutron and decays with tritium as a product.

   b. Boron captures a neutron and decays with tritium as a product.

   c. Activation of deuterium in water.

   d. Ternary fission - A fission resulting in three fission products, one of which is tritium. This process has a 0.1% yield.

   The production of tritium from power reactors around the world is less than one-half that naturally formed (approximately 1 to 2 million curies a year).

3. Weapons Testing as a Source

   The amount of tritium in the world from weapons testing has been steadily declining since the 1970's when atmospheric testing was curtailed.

   Atmospheric testing from 1945-1975 produced about 8 billion curies. This has decayed to about 400 million curies.

Notes

4. DOE Production of Tritium

DOE has produced tritium at the Savannah River Site with the use of a reactor. Tritium is commercially available from from Canada and the European Community for non-weapons use.

B. Uses of Tritium

1. Consumer Products

a. Gaseous tritium light sources
   - exit signs (1 Ci to tens of Ci's)
   - aviation landing aids (30-165 Ci per light)

   (1 curie of tritium has a mass of approximately 0.1 mg)

b. Luminizing industry: Self-luminous compounds for dials (several mCi's) and controls as well as other general industry uses.

2. Research - Tritium Labeling

Tracers for medical and laboratory research.

3. Department of Energy

a. Weapons development and applications

b. Fusion energy: As a fuel source

Notes

III. MODES OF EXPOSURE AND BIOLOGICAL BEHAVIOR OF TRITIUM - How can I be exposed to tritium and what would it do to me?

A. External Dose

- Tritium is not an external hazard.
- Tritium is not a dose concern if it is located outside the body.
- Tritium betas will not penetrate a dosimeter.
- We are interested only in tritium inside the body.

B. Internal Dose

Tritium is an "internal" radiation hazard.

C. Modes of Exposure

Tritium can deliver a radiation dose if it gets inside our bodies. Modes of entry include:

- inhalation
- absorption
- injection (cuts/wounds)
- ingestion

Notes

1. Inhalation

a. Tritium gas: is only slightly incorporated into the body when inhaled. Most tritium gas inhaled is subsequently exhaled. There are other chemical and physical processes to convert tritium gas to tritiated water.

b. Tritiated water vapor: Nearly 100% of tritiated water vapor inhaled is incorporated into body fluids/tissues.

c. Hazard: Exposure to tritiated water is approximately 25,000 times more hazardous than exposure to elemental tritium gas.

d. Special Tritium Compounds: consist of organically bound tritium and tritium particulate aerosols.

Exposure to organically bound tritium can be up to approximately 13 times more hazardous than exposure to HTO.

Exposure to tritium particulate aerosols can deliver up to approximately 20 times more dose to the whole body than exposure to HTO. The dose to the lungs from tritium particulate aerosols could be 2 orders of magnitude higher than from HTO.

2. Ingestion

***Ingestion*** may occur by eating, drinking, chewing tobacco, and applying makeup where tritium contamination is present. Always wash hands thoroughly when leaving areas where there is a potential for contamination, and never eat, drink etc. where tritium contamination may be present.

Notes

3. Absorption

Absorption is also a hazard because an individual can receive, in certain situations, 1/3 of their uptake from absorption through the skin if not properly using personal protective equipment.

a. Tritium gas: There is negligible skin absorption for tritium gas.

b. Tritiated water: Tritiated water can be absorbed through the skin. It has been observed that moisture on hands enhances absorption.

c. Solvents: Some solvents (organically bound tritium) can also go through the skin.

Tritium will penetrate gloves, therefore gloves must be changed at a prescribed routine basis.

D. Biological Behavior of Uptakes of Tritium

Tritiated water in the body acts just like water.

1. Distribution

Tritiated water is rapidly and uniformly distributed throughout the entire body. The Committed Effective Dose Equivalent (CEDE) from an uptake of one curie of tritiated water is 63 rem. Soluble organically bound tritium behaves in the body in a similar manner.

Stable tritium particulate aerosols and insoluble organically bound tritium behave in the body in a similar manner as the particulate to which the tritium is bound.

Notes

2. Biological Half-life

Half of the HTO is eliminated from the body in about 10 days. Through normal biological processes, it would take 70 days or more to eliminate 99% of the assimilated tritiated water.

Stable tritium particulate aerosols and insoluble organically bound tritium behave in the body in a similar manner as the particulate to which the tritium is bound and would have a longer half life.

E. Medical Treatment

The biological half-life can be shortened by increasing the water elimination in the body. Therefore, individuals who have uptakes of tritium are encouraged to drink water. Drinking copious amounts of water should not be done without a physician's guidance. Certain medical conditions may be affected by liquid intake.

IV. RADIOLOGICAL CONTROLS FOR TRITIUM - How can I protect myself from exposures to tritium?

Tritium can be present in a variety of chemical forms. Ongoing research indicates that the form of tritium which gives the highest dose (per unit intake) is tritium particulate aerosols. However, these compounds are not found in the quantities and various locations as tritiated water. If we can rule out special tritium compounds as being of concern, we assume it may be tritiated water.

The preferred hierarchy of control is as follows:

- engineered
- administrative
- personal protective equipment

Notes

A. Engineered Controls

1. Containment and Confinement

Containment or confinement is a series of physical barriers, minimizes exposure of workers.

Confinements such as glove boxes are almost always used when handling large quantities of tritium. However, hoods are acceptable for handling small quantities, such as in a laboratory.

2. Airflow

Maintaining negative ventilation is essential for the safe operation of a tritium facility. Airflow should be from areas of LEAST to MOST contamination.

3. Local Exhaust Ventilation

The primary advantage of local exhaust ventilation techniques is the removal of airborne tritium, regardless of its release rate or chemical or physical form. In addition, these techniques use relatively low volume rates compared to normal ventilation requirements.

Notes

4. Dilution Ventilation

Dilution ventilation is the once-through flow technique of exchanging outside air for inside air for comfort and the reduction of airborne sources.

5. Storage

Tritium can be stored in storage beds. Metal tritide and uranium hydride are the most common for these storage systems. Tritium is generally released by heating the metal tritide.

B. Administrative Controls

There are many administrative controls to reduce doses. The following are just a few that should apply to all sites:

- limitation of access time
- procedures/RWPs
- postings

For tritium and tritium compounds, 10 CFR 835 Appendix D requires posting contamination areas based on removable contamination values of 10,000 dpm/100cm$^2$.

Notes

C. Personal Protective Equipment

1. Air Supplied Suits

Because of the absorption through the skin associated with the use of respirators and other breathing apparatus, air-supplied plastic suits that completely enclose the body are widely used by facilities that handle large quantities of tritium.

2. Protective Clothing

Protective clothing (PC), or anti-contamination clothing (anti-Cs), is used to minimize the spread of contamination from contaminated to clean areas.

In many operations, the hands and forearms of workers are vulnerable to contact with tritium surface contamination. The proper selection of gloves and glove materials is important. In many instances a plastic/water proof suit is required.

V. MONITORING FOR TRITIUM - How do I know if tritium is present?

Notes

A. Personnel Monitoring

1. External Dose

Dosimeters are not typically used to monitor for radiological doses resulting from tritium. The weak energy beta radiation will not penetrate the dosimeter.

insert any site specific monitoring procedures)

2. Internal Dose

The best method used to determine if an individual has an uptake of HTO or soluble organically bound tritium is by bioassay (urinalysis). Routine urine samples, collected at some predetermined frequency and counted for the tritium content, provide a very sensitive measurement of tritium in the body. This is especially true if the time of uptake is known.

Air sampling results may be used to assess dose from other types of special tritium compounds.

3. Routine Versus Non-Routine Bioassay Monitoring

a. <u>Routine</u>: Routine urinalysis is conducted on a preset periodic basis.

b. <u>Non-routine or Special</u>: Non-routine bioassay is done whenever a potential exposure to tritium is suspected.

(insert site specific bioassay procedures)

Notes

B. Workplace Monitoring

Air monitoring and surface contamination surveys are used to verify that loose contamination is not present. They provide an early indication of potential problems.

1. Airborne Tritium Monitoring

Airborne tritium monitoring is used for:

a. Prompt detection of airborne contamination for worker protection;

b. Determination of the status of processes; and

c. Identification of any leaks in primary or secondary containments or confinements.

2. Contamination Surveys

Despite contamination control measures, tritium is easily spread.

All workplaces shall be surveyed for contamination levels on a regularly scheduled basis. The frequency of such surveys will depend on the potential for dispersement of the tritium-contaminated material in the area and the quantity of tritium in the area. During routine surveys, all work enclosures, work surfaces, floors, equipment, etc., within the workplace should be surveyed.

Notes

At the surface contamination levels in 10 CFR 835 Appendix d, tritium is difficult to measure directly because the low-energy beta is readily absorbed in air and the window of the detector. Normal frisking methods (use of pancake probe) will not detect tritiated water.

Surfaces are normally wiped (smeared) with a small paper, either dry or moistened, which will pick up loose tritiated material. The wipe is then normally counted by liquid scintillation techniques.

VI. TRITIUM WASTE MINIMIZATION AND HANDLING- Why is it important and how do you minimize tritium waste?

(insert site specific controls)

Methods below are given as a reference only.

A. Minimizing Tritium-Contaminated Waste

1. Avoid generating wastes by not bringing unnecessary material into the controlled area.

2. Whenever possible, avoid use of porous materials or those known to be highly permeable to tritium.

3. Designate an area to store contaminated tools for reuse or consider all tools in the area to be contaminated.

Notes

4. Plan work so that, whenever possible, construction and clean maintenance can be done in a clean area.

5. When transporting items contaminated with tritium, adequate contamination control such as wrapping in plastic or placing in sealed containers should be considered.

B. Minimizing Mixed Waste

(insert site specific controls)

Methods below are given as a reference only.

1. Use non-hazardous cleaning materials for decontamination whenever possible.

2. Segregate radioactive-only from hazardous-only at the source.

3. Explore the use of other materials which are non-hazardous for use in radiological areas to prevent the generation of mixed waste.

VII. RESPONSE TO ABNORMAL CONDITIONS IN THE TRITIUM FACILITY- What should I do in an emergency involving tritium?

To properly deal with unexpected adverse situations occurring in a tritium facility, a well-thought-out response program and personnel trained to execute the response should be in place.

Notes

A. Abnormal Conditions

Abnormal conditions in a tritium facility could include:

- fire/explosion
- natural disaster
- tritium releases
- other hazards

Personnel found contaminated should follow site specific decontamination procedures which would typically include showering with cold water and the use of mild detergents.

B. Facility Alarms

(insert site specific alarms and emergency response procedures)

C. Facility Emergency Responses

(insert site specific alarms and emergency response procedures)

VIII. LESSONS LEARNED

(insert site specific lessons learned)

IX. SUMMARY AND REVIEW

**CONCLUDING MATERIAL**

| **Review Activity:** | | **Preparing Activity:** |
|---|---|---|
| DOE | Field Offices | DOE-EH-52 |
| DP | RF | ***Peter V. O'Connell, CHP,*** 301 903 5641 |
| EH | ID | **Project Number:** |
| EM | SR | TRNG-0020 |
| NE | OH | |
| SC | RL | |
| GC | | |
| IA | | |
| RW | | |
| NN | | |

| National Laboratories | Operations Offices |
|---|---|
| BNL | AL |
| LLNL | NV |
| LANL | OAK |
| PNL | OR |
| Sandia | CH |
| ANL | |
| New Brunswick | |
| ORNL | |

Area Offices

Amarillo Area Office

Kirtland Area Office

Princeton Area Office

Fernald Area Office

Kansas City Area Office

Miamisburg Area Office